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Process for establishing a digital data connection operating via a transmission medium that is subject to disturbance effects.

Transmission of digital data demands that data can be received error-free or else, at the very least, in a manner whereby the error rate can be controlled, ie. whereby the digital connection quality can be controlled.

In the case of a radio wave connection, the received signal level must result in a signal to noise ratio that is capable of supplying the desired signal quality even when atmospheric disturbances are present.

When estimating the projected signal level present at the receiver, any calculation must account for the transmitter output power, the aerial gain, any losses that affect the electrical conductors supplying them, the distance across which the radio wave connection operates and any obstacles or disturbances known to affect the connection.

The receiver must therefore be sensitive enough to detect any signal that is equal to, or indeed weaker than, the aforementioned projected level. The aforementioned calculated values together constitute a projected energy status for the connection. The attenuation in passage through the atmosphere is, however, liable to vary depending on atmospheric conditions such as rain or other such disturbances so that it is important to build a safety margin into the inequation referred to above with respect to the sensitivity of the receiver, in order to ensure that any increases in attenuation effects are duly catered for.

It is good practise to compare the actual energy status with the projected energy status as soon as the connection has been established, as the direction the aerials are pointed in or other unforeseen disturbances constitute unknown factors.

Using a traditional approach, the transmitter level is progressively reduced for this purpose to the point where the receiver is operating at its minimum threshold detection level. At this point it detects and signals the presence of multiple errors, thus alerting the

service operator to the fact that the threshold level has just been reached.

Under these operating limit conditions the difference between the transmission level and the reception threshold constitute the attenuation of the connection. In order to increase this difference so as to have a safety margin in the connection energy status, making it possible to overcome any temporary degradation in the transmission, the transmission level must be increased since the receiver already has, in practice, an optimal sensitivity level, ie. a minimum threshold level compatible with interference levels.

Given the long-range nature of the connection, the service operator is provided in practice with a signal channel in this connection, thereby ensuring that he can operate or monitor one end of the connection from the other end: the transmitter power level can be altered remotely from the receiver, while from a position in the vicinity of the transmitter, it is also possible to receive back the afore-mentioned measurement results of the power level received and / or of the error rate, post-correction.

In practice however, the post-correction error rate varies swiftly over a limited range of reception levels. When the received signal level lies above and beyond this range, the auto-correction code eliminates any errors that are present thereby making it impossible to acquire any threshold data. When the signal level is below this range, the auto-correction code error limit processing rate is exceeded and this code may even potentially make false corrections, thereby adding errors. Furthermore, the signal channel provided by the connection will also cease to operate.

This invention is intended to simplify the establishment of a radio or other such data connection.

The invention therefore relates to a process that can be used to establish a digital data connection between a transmitter and a receiver, linked by a transmission medium that is subject to disturbance effects, a process in which a data signal is transmitted via the transmission medium, which data are protected by an error detection and correction code

of known effectiveness, while adjusting the signal level that is received by the receiver so that only a limited number of errors are apparent, and the transmission level is then increased ensuring that a safety margin is built-in to counter the effect of disturbances upon reception, the process being characterised in that:

- a pre-correction error rate measurement point, for a received level, is determined upon reception,
- depending on the effectiveness of the code with respect to the error rate, an anticipated post-correction error rate curve and its position in relation to the measurement point are determined,
- an acceptable error rate limit at some point along the curve is chosen, and,
- starting from the reception level on the curve that relates to the error rate limit, the transmission is increased according to the projected safety margin.

This gives access to accurate information that can be used to determine the sensitivity of the receiver to noise, since all the errors are detected and a count thereof can be undertaken at any point across a much wider range of received signal levels than the range after correction. The error rate / received signal level slope is much less pronounced before than after correction, thereby ensuring that an error count can be undertaken over a limited period of time without the need accurately to control the signal level and without running the risk of obtaining no accurate data.

Put another way, use is made of raw data, the error rate of which changes gradually over a wide range, and not corrected data, the error rate of which is practically binary in nature: either no errors or too many errors, thereby rendering it practically useless.

The invention is more clearly understood by referring to the following description, which illustrates one embodiment of the invention, together with the appended drawings:

- Figure 1 is an outline of a digital connection, in this case a radio connection, between a transmitter and a receiver, established in the manner of the process of the invention, and
- Figure 2 illustrates the reception error rate as a function of the received signal level,

before and after correction using an auto-correction code.

The radio connection illustrated consists of a transmitter 1 and a receiver 3, with symbol 2 signifying the route travelled between them by the radio waves through the transmission medium, in this case air. The connection is bi-directional in this case and can also constitute a link in a propagation chain. ie. a service operator who is located at either item 1 or item 3 therefore checks a transmitter of a connection as well as a receiver of another connection and needs to be able monitor the equipment that is located at the other end of these connections. Therefore this example aims to permit the connections to be easily established from either end of the link. However, in the interest of clarity, we will limit ourselves to giving a detailed explanation of how connection 2 is established in the direction indicated.

The process consists of transmitting a data signal via the transmission medium 2, the data being protected by an error detection and correction code of known effectiveness, while adjusting the signal level that is received by the receiver 3 to ensure that only a limited number of errors are apparent, and the transmission level is then increased to provide a safety margin against disturbance effects upon reception, a process wherein:

- a pre-correction error rate measurement point, for a received level, is determined upon reception,
- depending on the effectiveness of the code with respect to the error rate, an anticipated post-correction error rate curve and its position in relation to the measurement point are determined,
- an acceptable error rate limit at some point along the curve is chosen, and,
- starting from the reception level on the curve that relates to the error rate limit, the transmission is increased according to the projected safety margin.

The test data signal produced by a quasi-random generator 11 for establishing the connection, is cyclically fed by packets into successive frames of the transmitter 1. The data activate an intermediate frequency modulator 12 that is succeeded by an amplifier 13. The modulated signal passes through a mixer 15 in order for its frequency to

transposed with the aid of a local oscillator 16, which is connected to the mixer 15, then amplified via a power amplifier 17 which transmits it by radio. A calibrated attenuator 14 in this case connects the amplifier 13 and the mixer 15. A micro-controller 10 filters out any transmission level remote commands received via a receiver signal channel and, in this case, communicated via radio waves that are travelling in the opposite direction to the connection 2, and consequently controls the attenuator 14.

The receiver 3 has at its input a low noise amplifier 32 that controls a mixer 33, connected to a frequency transposition oscillator 34, with an intermediate frequency filter 35 downstream thereof. The intermediate frequency signal obtained from filter 35 is then fed into a demodulator 36 which supplies the resultant data together with a clock signal of corresponding timing, to operating circuits and which calculates the number of errors detected in each received packet, while that particular packet is being corrected by an error detection and correction code, of known effectiveness, that it applies to the packet of received data. This last piece of information concerning the number of errors or error rate for raw data is then passed on to a micro-controller 31 which processes the data and passes them back to the micro-controller 10 via the signal connection, so that the raw error rate can be measured before any errors have been corrected. A calibrated circuit 37 that detects the received field and that is connected to the output of filter 35 is fitted here so that the aerial access level can be measured with accuracy. It enables the measured error rates to be linked with the received field level. However, it will become clear that, as explained further on in this text, it is the error rate and not the received signal level that is required in order to implement the process.

The diagram is purely informative in nature, as the logic circuits are in this case fitted inside a PC, which is used to control the transmitter signal level 1 (or the receiver 3) when transmitting any data that are measured or controlled remotely.

A service operator can run software that will automatically adjust the transmission level via a simple keyboard and screen / mouse combination. This software records the measurements of the error rate and of the received signal levels and, depending on their

value, automatically sets the service transmission level, in the manner explained further on in this text.

The test bit sequence corresponds to any data that have been protected by the addition of supplementary bits which are based on the data themselves or can be the result of all the data being merged into a new block of data. These supplementary bits bear a correlation to these data, this means that on reception any error bits can be detected, localised and thus corrected by effectively forcing bits to adopt their opposite binary state. It is then possible to mathematically determine the effectiveness of the protection code thus generated, as a function of reception error rate, depending on the percentage of supplementary bits and the size of the data that require protection. In this way a low average error rate upon reception ensures that the appropriate corrections can be made, whereas a higher average rate will sometimes, if only transiently, correlate to a rate that momentarily produces an excessive number of errors, which will be detectable as such but without it being possible to localise and thus correct these errors.

The aforementioned auto-correction code therefore enables the system to operate at a much lower reception level than would otherwise be possible without resorting to the use of correction code. Once the effectiveness of the correction code is recognised mathematically, it is quite acceptable to view the code as having the effect of artificially raising the signal level actually received and therefore, as a result of this, reducing the error rate.

Figure 2 displays a log / log scale graph in which the y-axis of curve C1 represents the pre-correction error rate T against the absolute level N of the received electric field signal, expressed in dBm. The curve clearly indicates that the error rate T varies inversely with the received signal level N.

If the statistical noise distribution over time is known, then the shape of curve C1 is also known, put another way, once the average power of the noise is known, it becomes possible to estimate the probability that an instantaneous peak of noise (addition of

several pulses, or bursts, of noise from a variety of sources, that occur at random moments in time) will exceed the average level by a set factor, thereby risking detection. The aforementioned probability decreases exponentially as a function of the aforementioned amplitude factor. Fixing a point (S1) on the curve C1 therefore determines the position of all the points occurring along the curve.

The curve C2 correlates to the curve C1 once the errors have been corrected by the code in the demodulator 36. For a given received level N, curve C2 describes an error rate T that is much less than that given by C1. As explained earlier on in the text, a low error rate on curve C1, of the order of 10^{-6} for example, corresponds to fully effective correction by the code, so that the curve C2 lies well below C1 at almost zero values. Conversely, in the case of a higher average error rate, from 10^{-2} to 10^{-3} for instance, curve C2 is closer to the curve C1 because bursts of noise are produced more often, which have a cumulative effect thereby exceeding the detection threshold and reducing the effectiveness of the correction code.

Therefore, as has just been explained, the effectiveness of the code makes it possible to determine the position of the post-correction curve C2 relative to the pre-correction curve C1. For a given set error rate T, for example 10^{-6} at point S1, it is then possible to deduce and determine the intersection point on curve C2, ie. the margin of gain in dB, for example 5dB at a set level, that the auto-correction code produces when attempting to overcome the effects of noise other than by increasing the received level.

In this case an error rate threshold of $T = 10^{-3}$ has been chosen, which corresponds to a received threshold level N2 (point S2).

In accordance with this process, point S2 is determined by using the PC software in order to determine a point S1 by adjusting the transmitter level 1 in order to be able to detect errors at the receiver 3.

In this case, a strong enough transmission level is used at the beginning to ensure that the

signal connection is operating and is then reduced (arrow F1) to a point N1 where the pre-correction error rate T can be measured for a limited period of time, not exceeding a few minutes and resulting in a not insignificant number of errors. For example, if the error rate were 10^{-6} at the point S1, a connection operating at 10^{8} bits per second would result in 100 errors per second and therefore provide an accurate measurement of the error rate. However, reception at a level in excess of S1 and corresponding to an error rate, T, of 10^{-8} for example, would also result in about a hundred errors after a time period of from one to two minutes.

Once the position an arbitrary point S1 that will result in a useable error count has been accurately pinpointed on the curve C1, the position of the curve C2 in relation to the point S1 can then be deduced by determining the two points along the curve C2 which have the same x and y-axis respectively as the point S1, alternatively, by plotting the curve C1 and vertically and/or horizontally translating each point on the curve by a distance specific to each one, depending on the effectiveness of the code at the particular point in question. As the selected error rate threshold T is 10^{-3} in this particular case, the curve C2 results in the level N2 at point S2. Hence the position of the point S2 can be determined (arrow F2) from each starting point S1.

As mentioned earlier in this text, the error rate T is the parameter required which must be known in order to ascertain whether or not one is currently located on the curve C1. As indicated in the scale drawing (logarithmic), the absolute received level N1 does not act as an absolute level when determining the further increase [M – (N1 – N2)] in the level the transmitter 1, corresponding to arrows F2 and F3 illustrating the effectiveness of the code for the error rate (relative difference N1 – N2) and the selected margin factor M respectively.

As mentioned previously, in this case the data connection provides a data exchange signal channel between the transmitter 1 and the receiver 3, enabling a service operator and the PC to receive for example, via the connection established in the opposite direction, measurements of the received level (37) and of the pre-correction error rate (36), while

located at the transmitter 1. When at the receiver 3, the PC or operator can then control the programmable attenuator 14 remotely, thereby adjusting the transmission and reception levels accordingly. Generally speaking, the attenuator 14 can be fitted at any point in the data transmission chain within the transmitter 1 or the receiver 3. As the pre-correction error rate (10^{-6} to 10^{-8} for instance) remains limited in nature, the logic connection, and therefore the connection-establishing signal channel, always remains connected since the code retains all its effectiveness at the output of the demodulator 36. However, it should be noted that it is acceptable to set up a signal channel that operates via the telephone network or other such connection.

As the filter 35 used in this particular case uses a relatively wide pass-band in relation to the useful channel width, a radio interference transmitter with a frequency close to the useful band and of a much higher level than the level N1 of the signal used to measure this band would risk raising the detected signal (37) to a level that does not share a common measurement with that of the useful signal N1. In order to detect the presence of such disturbances and thus check the validity of the measurement of the signal level received from the transmitter 1, the transmission level is varied by a set factor and then a check is made that the level of the received signal N1 varies by the same factor. However, the presence of a radio interference signal, which adds a constant to the measurement of the received signal level, does distort the proportionality that exists between the transmission and the measurement upon reception.

Any divergence from proportionality between the fluctuations in transmitted and received levels N1 can therefore be measured and the measurement of the level N1 can be corrected as and when necessary. However, the possible correction will not be very accurate if the interference signal is much stronger than the useful signal. To avoid this sort of inaccuracy, an additional control measurement of the received level is made, once the transmission level has been previously increased by the set factor and the value of the additional measurement decreased by the stated factor, for example 25 dB, is retained as the initial measurement value N1. This then results in the interference signals being brought to a low level, in terms of relative value, with respect to the useful signal.

This is accomplished by varying the transmission level by controlling the calibrated attenuator 14 of the intermediate frequency stage of the transmitter 1 remotely, in order to suppress the desired attenuation, in this case 25dB, and for example suppress any attenuation. As the attenuator 14 is located within a stage operating on the basis of limited power, and upstream of the power amplifier 17, its operational interference losses are minor and can therefore be offset by simply increasing the line gain.

Once the point S2 has been determined, the transmission is increased (arrow F3) by the predetermined safety margin factor M. Existing standardised tables describing the probability of interference affecting the connection 2 as a function of the aforementioned margin, then allow selection of the acceptable risk error rate for the connection. A margin M of 50dB corresponds to a sufficiently small, and therefore acceptable, risk of error. The adjustment of the gain of an amplifier such as 17 can therefore be used to increase the level of the transmitter 1 should the action taken upon the attenuator 14 alone prove to be insufficient. During operation a useful signal of data to be transmitted will take the place, in the frames, of the test signal supplied by generator 11.

This invention does not have to be used in conjunction with the specific transmission support or medium, which may therefore, for example take the form of an electrical or optical cable.